Acknowledgements

This has been a nearly five-year effort, with references and changes being added right until the very end in July 1998. The field of seagrass planting for restoration and mitigation continues to grow and we ask the reader to recognize that this document represents an arbitrary point in time to summarize and reflect on the status of the science.

We would like to thank the many people who took time to answer questionnaires, return phone calls, emails, unearth and fax and mail reports, send reprints, share unpublished material and talk to us on the phone and in person right up to the last bell. We cannot list you all without fear of omission; the list involves dozens of people from private and public sectors all around the country. We thank you all very much. Thanks are extended to the many people who contributed to the non-anonymous peer review: Mike Durako, Robert Hoffman, Curtis Kruer, Robin Lewis, Mary Ruckelshaus, Arthur Schwarzschild, Fred Short, Ron Thom, Edward Townsend, Susan Williams, Paula Whitfield and Sandy Wyllie-Echeverria. However, we did not always concur with the reviewers' recommendations and their views are not necessarily those expressed herein. Arthur Schwarzschild drafted the sections on temperature and salinity effects. Patricia Hay, drafted the executive summary and Chapter 5, the Manager's Summary.

Special thanks are extended to Ed Townsend and Paula Whitfield for their tireless editorial work and their contributions to our research base over the years. For this project, Paula spent days reading all the documents and creating a relational data for the comparative analysis. Among many other tasks, Ed and Paula marshalled the literature citation effort and conducted extensive editing tasks. Gene Cope facilitated production of the color plates. Patti Marraro edited the references. Erik Zobrist graciously provided a last-minute review. Sandy Rodgers calmly and professionally performed the editing and typesetting. Finally, thanks are extended to our contract monitors, Isobel Sheifer, David Johnson and Mike Murphy of NOAA's Coastal Ocean Program for their support and patience in the long production of this document. Funding for this document was provided by the Beaufort Laboratory of the National Marine Fisheries Service, NOAA, the NMFS Restoration Center, and a grant from NOAA's Coastal Ocean Program.

List of Appendices

APPENDIX A
Glossary

allele(s): any of the different forms of a gene that occupy the same locus on homologous chromosomes (the latter being the chromosomes that pair during meiosis)

allozyme: one of several forms of an enzyme which is coded for by different alleles at a given locus on a chromosome; contrast with isozyme

apical: as in apical meristem; the distal unit of a seagrass plant that gives rise to new plant compenents, leading to vegetative expansion

arbitrary sample: a sample taken without regard to potential bias in the location, quality or quantity of the variable being sampled

areal coverage: coverage of the sea floor by seagrass expressed on a unit area basis

asymptote(s): portion of a graphed curve that levels out with respect to the independent variable

baseline acreage: the amount of habitat acreage at some past time that is used as a reference for computing subsequent changes in habitat abundance

Beer's Law: a mathematical expression that describes the exponential decay of light quantity with increasing water depth as a function of turbidity

bioturbation: the physical disruption of the sea floor and/or seagrass bed by the activity of any number of animals (e.g., rays, crabs, fish).

clone: here, an assemblage of seagrass shoots formed through asexual reproduction, arising from a sexually-reproduced individual

compensatory mitigation: the establishment of a wetland area for the purposes of offsetting a permitted loss of a like wetland

compliance: the degree to which stated project goals are attained

continuous cover: a seagrass bed with little or no open areas of unvegetated sea floor

coverage rate: the rate at which planting units colonize the sea floor expressed on a unit area basis per unit time

creation: in reference to wetlands, the conversion of persistent non-wetland area into a wetland, contingent upon the status of the non-wetland area having been persistent through 100-200 years

cultivated seagrass: seagrass plants that are generated under any one of several anthropogenically-mediated techniques (e.g., tissue culture, micropropagation)

donor bed: an existing seagrass bed from which transplant material is harvested for planting elsewhere

dredge and fill: the act of dredging or filling of a habitat, particularly in reference to the management of this activity under sec. 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act

enhancement: the increase in one or more values of all or a portion of an existing wetland by man's activities, often with the accompanying decline in other wetland values

erosion scarp: a point of erosion in a seagrass bed that results in vertical relief and often exposes seagrass roots and rhizomes.

genet: a group (here seagrass shoots) derived by asexual reproduction from a single original zygote such as a seedling or isolated shoot (usually with a rhizome apical where this is required for clonal expansion)

genotype: the heritable genetic constitution of an individual

growth strategies: the rate at which individual species of seagrass reproduce by either sexual (seed production) or asexual means (tillering of rhizomes across the bottom accompanied by vegetative production of new short shoots)

habitat: an unspecified spatial scale which has physical, chemical and biological attributes conducive to the maintenance and propagation of biota

habitat functions: services provided to the ecosystem by a given habitat type (e.g., shelter, stability, refuge, nursery)

impact avoidance: avoidance of any alteration of an existing wetland

impact site: a site containing jurisdictional wetlands which is being, or is going to be altered by anthropogenic actions

in-kind: planting a wetland species that is the same as the one that was damaged

isozyme: one of several forms of an enzyme that is produced by different (nonallelic) loci; contrast with allozyme.

jurisdictional wetlands: wetlands under the management jurisdiction of a regulatory agency

long shoot: a collection of short shoots physically located on the same rhizome

lower depth limit: the depth to which seagrass can grow which is determined by the amount and possibly the quality of available light; i.e., compensation depth

meristem: as in apical meristem; the portion of a plant that contains tissue which divides and gives rise to similar cells and/or plant structures (e.g., tissues, organs, rhizome, roots, leaves)

metapopulation: a group of conspecific populations co-occurring in time, but not in space

minimization: minimizing the degree of alteration of an existing wetland by modification of a project plan

mitigation: the actual restoration, creation, or enhancement of wetlands to compensate for permitted wetland losses

monitoring: collection of habitat attributes (e.g. depth, cover, species composition or planted seagrass growth) relative to assessment of site conditions, planting site suitability, or planting performance.

no net loss: a quantitative evaluation which compares habitat area replaced or conserved with the habitat area lost

off-site: planting of a wetland as some form of mitigation at a location not in immediate proximity to the physical location of the damaged wetland for which it is to compensate

on-site: planting a wetland on an area which has suffered a loss of a wetland habitat

out-of-kind: planting a wetland species that is not the same species as the one that was damaged or lost

PAR (photosynthetically active radiation): wavelengths of light between approximately 400 to 700 nanometers

patchy distribution: seagrass beds (areas where rhizomes overlap) and associated unvegetated bottom; either distinct, isolated patches of seagrass in a predominantly unvegetated sea floor or meandering patterns of unvegetated bottom in a predominantly vegetated area

peat pot: in reference to a seagrass transplanting technique where plugs of seagrass are removed and placed into commercially available, small cups constructed of compressed peat; the plug and peat pot container are then planted in the sea floor

permitting agency: a resource management agency (e.g., state, federal) that has statutory authority for issuing or commenting on permits dealing with wetlands modifications

phenotypic plasticity: the capacity for marked changes in a phenotype as the result of environmental influences upon the genotype during development

pioneering species: a species of seagrass with a growth strategy than enables it to rapidly colonize unvegetated sea floor

planting performance: attributes of a planted area which can be used as indicators of project success; e.g., planting unit survival, planting unit population growth and coverage rate.

planting ratio: the ratio of planted, and eventually, persistent seagrass acreage to the amount of acreage lost in a given project

planting unit(s): an individual core, plug, staple, peat pot, sod, etc., and the associated plant material used in a planting operation

plugs: in reference to a seagrass planting technique where hollow tubes are used as a coring device into a seagrass bed, thereby harvesting the sediment "plug" in the tube with the associated seagrass

propagule: any portion of a seagrass plant that is capable of colonizing a new site after becoming detached from an existing plant (e.g., seeds, plant fragment with leaves and roots)

propeller scarring: typically a long, linear furrow excavated in the bottom as the result of operating vessels in water depths shallower than the draft of the drive unit (propeller); results in excavation of seagrass

PU: planting unit

ramet: a member of a clone, assumed to be of identical genetic composition as the rest of the clone, and that will continue to survive if separated from the clone

random sample: a sample taken such that each sample unit has an equal (unbiased) probability of being selected

restoration: returned from a disturbed or totally altered condition to a previously existing natural, or altered condition by some action of man; refers to the return of a pre-existing condition

rhizome: sensu Websters' Collegiate Dictionary: a somewhat elongated, usually horizontal plant stem which produces shoots above and roots below and is distinguished from roots in possessing buds, nodes and scale like leaves

rhizome apical: the meristematic region at the terminus of a long shoot that gives rise to further rhizome growth and differentiates to give rise to short shoots

rhizosphere: portions of the sediment occupied by the roots and rhizomes of seagrass

salvage operation: transplanting seagrass from an area where activities are planned which will destroy that seagrass

Section 404 permit process: references section 404 of the Clean Water Act which provides the statutory authority to specific federal agencies regarding dredge and fill activities in the waters of the United States

sediment resuspension: the transfer of sediment from a resting position on the sea floor to the water column as the result of some external action such as wind waves, tidal currents, or a vessels' propeller(s)

short shoot: an individual meristem located on a long shoot which produces leaves and roots

site survey: a quantitative assessment of the amount of plant material to be disturbed, its distribution and the environmental conditions at impact and planting sites prior to initiating a project (see also monitoring)

slow release fertilizer: a fertilizer which releases nutrients over ime at a given temperature

staple: in reference to a seagrass planting technique where plants are washed free of sediment and typically are attached to a U-shaped metal bar (staple) which is then inserted points down into the sediment, pinning the seagrass to the sea floor

success (planting): although the definition of this term may be changed with the goals of the project at hand, a broadly applicable form is as follows: the unassisted persistence of designated seagrass coverage for a prescribed period of time (suggested minimum of 5 years)

turbidity: the degree of opacity of the water column as a result of dissolved and suspended material in the water column

unassisted persistence: seagrass beds maintained by natural recruitment and have not been assisted by any deliberate anthropogenic manipulation

unvegetated sea floor: the portion of the estuarine floor which is not colonized by rooted submerged aquatic vegetation

water transparency: a measure of the degree of water clarity

wild stock (stands): naturally-occurring seagrass beds

APPENDIX B

Seagrass Species Characteristics

(Alphabetical order by scientific name; modified from Fonseca 1994; for greater taxonomic detail see den Hartog 1970, Phillips and Menez 1988)

Halophila decipiens: An extremely fragile seagrass that is often confused with some rhizophytic algae, such as *Caulerpa* spp. The leaf blades are 10 to 25 mm long and ~5 mm wide and occur in pairs at each rhizome internode (one root per node). The blade margin is finely serrated and the end of the blade is rounded. Blades are ~1 cell thick and translucent. Rhizomes are typically 1 mm in diameter. The entire plant community can easily be dislodged from the sediment although because of it's high fecundity and rapid rhizome extension rate (Josselyn et al. 1986) it is a ruderal or opportunistic species. Plants cannot tolerate burial and will disintegrate beyond recognition in 24 h if buried, making the carbon and other nutrients fixed by *Halophila* the most labile of any seagrass. Although diminutive, this seagrass genus can significantly enhance sediment stabilization (Fonseca 1989b). In general, this genus can withstand very low light conditions (~1% of insolation as opposed to ~20% for other genera) and occurs at great depths (>40 m; Josselyn et al. 1986, Kenworthy et al. 1989), or in shallow turbid water, under docks or as an understory to other seagrass species.

Halophila engelmanni: Similar in an ecological context to *H. decipiens* but rather than having leaf pairs at each rhizome node, there is one stem per rhizome node with upwards of 7 leaves on each stem. Blades are more elongated and pointy than *H. decipiens.*

Halophila johnsonni (threatened species): Also similar in an ecological context to *H. decipiens* and also has a leaf pair at each rhizome node. Blades are more elongated and pointy than *H. decipiens* and veins sweep upwards from the center line of each leaf at nearly 45 degrees, but blade margins are not serrated.

Halophila hawaiiana: Again, similar in an ecological context to *H. decipiens* and also has a leaf pair at each rhizome node, Blades are more elongated and pointy than *H. decipiens* although unlike *H. johnsonii*, leaf tips are more rounded.

Halophila ovalis:Very similar in appearance to *H. decipiens* except *H. ovalis* has 10-25 leaf veins whereas *H. decipiens* only 6-9 leaf veins.

Halophila minor: Smaller than *H. decipiens* with a maximum length of 14 mm and has only 3-8 pairs of leaf veins.

***Halodule wrightii* (contrast with *Ruppia maritima*):** This species was once classified under the genus *Diplanthera*. References from earlier than 1975 often refer to this species by that name. It has a lower depth limit equal to turtle grass and manatee grass. It also can occur in very shallow water and it is noted for its relative tolerance to desiccation once rooted. It often forms large pancake-like patches reaching 30 m diameter) or extensive meadows on shallow shoals and flats, experiencing regular exposure at low tides (the basis for its common name). The fine (1-3 mm width) blades occur in groups of two to four on a shoot and vary in length according to depth as does turtle grass. Blade lengths range from as small as 5 cm to over 40 cm. This species forms very dense beds, with upwards of 5000 shoots per m^2 (although 11000 can occur; pers. obs). Flowers are difficult to locate as they occur on the base of the shoots near the sediment surface. Rhizomes are fairly shallow, rarely being deeper than 5 cm, although roots may extend for 25 cm or more. Rhizomes may extend into the water column with attached short shoots which appears to be a form of vegetative propagation. These rhizomes may be easily harvested and are efficiently transplanted with the staple method.

This species can easily be confused with widgeon grass. Four visual clues separate them: (1) widgeon grass produces extensive flowering stalks often reaching a meter in length, with numerous seed clusters resembling miniature rattlesnake rattles while flowers in shoalgrass are rarely seen; (2) the blade tip of shoalgrass forms a miniature three-point crown, with the two leaf margins and central vein of the leaf forming the points. Widgeon grass blades taper to a single sharp point; (3) shoalgrass rhizomes are usually very straight and white often somewhat zig-zagged when viewed from above and may be green or white; and 4) shoalgrass has two roots per node on the rhizome whereas widgeon grass has one root per node.

Phyllospadix scouleri: Found on rocky substrate and appears much like *Zostera*; blades can be 2 meter long but compared with *Zostera*, are much narrower, only up to 4 mm wide. Rhizomes can be covered with many fibers. Abundant, but not limited to, north of Monterey, California.

Phyllospadix serralatus: Found on rocky substrate primarily north of southern Oregon. Leaf margins show fine serrations.

Phyllospadix torreyi: Also found on rocky substrate but deeper than the other *Phyllospadix* spp.; abundant but not limited to south of Monterey, California. Blades are different from the others of this genus in that they emerge from a sheath that is wider than the blade itself with only one blade per sheath.

***Ruppia maritima* (contrast with *Halodule wrightii*):** This species is a favorite food of migratory waterfowl, a fact on which its common name is based. This species does not usually form a rhizome mat as dense as that of shoalgrass, but does much to stabilize the bottom. This species is set apart from all other seagrasses in that it can grow in both fresh water and hypersaline conditions (> 70 ppt). See shoalgrass for further description and contrast.

Syringodium filiforme: This species is easily distinguished from all the other seagrass species. It is nearly cylindrical. Its long erect blades are ~ 2-3 mm in diameter and there are usually only two leaves per shoot. These beds often accumulate a large under story of unattached macroalgae. The rhizome system varies in depth, between 1-10 cm. Flowering produces extensive branching which extends up into the water column, similar to widgeon grass grass but not as extravagant. Rhizomes may extend into the water column with attached shoots as described for shoalgrass, again presumably as a means of producing vegetative (as opposed to seed) propagules. As with shoalgrass, these propagules make excellent transplanting stock with no app

Thalassia testudinum: This species is one of the most well-known seagrasses in the subtropical regions of the U.S. It is a favorite food of the endangered green sea turtle, hence its common name. Its broad (often > 1 cm wide) deep green, strap-like blades (usually three to a plant but may often have upwards of five) cannot easily be mistaken for any other marine submerged aquatic macrophyte. Leaf length of the plants depends on water depth (as is the case with most seagrasses) and varies from ~10 to 75 cm. The leaves emerge from the sediment at the top of a vertical rhizome which rarely protrudes above the sediment surface. The thick, fibrous rhizomes from which the individual shoots originate are often located in excess of 20 cm into the sediment. This species develops flowers which emerge from the sediment next to the short shoot. Once fertilized, a round seed the size of a small acorn will be produced.

Seeds have been successfully used in planting projects. This species is noted for its longevity (sometimes > 10 yr. for an individual shoot) and the dense, extensive stands.

Zostera asiatica: Similar in appearance to *Z. marina* except that there are many more roots per rhizome node and sometimes emerge from the side of a short shoot. Multiple sheathes can occur on a single shoot which does not occur in *Z. marina*.

Zostera marina: The most common temperate seagrass species. Tremendous variation in size is reported from 30 cm to over 200 cm long. This species occurs on both coasts of the U.S. The rhizome is brown with roots located only at the rhizome nodes. A single shoot occurs at the end of each rhizome. A sheath encompasses 3-5 strap-shaped leaves. The leaf tip is rounded, sometimes with a very small point at the apex.

Zostera japonica: Appearing to be a smaller version of *Zostera marina*, this recently introduced species occurs as a *Z. marina* under story or in intertidal areas not colonized by *Z. marina*. Leaves are narrow, rarely wider than 15 mm and only ~30 cm long. Also unlike *Z. marina*, the blade tips may be asymmetrical or have longer margins than the center (like *Halodule*).

APPENDIX C

Partial List of Equipment

This Appendix was modified from Fonseca 1994 and Merkel 1992; see Merkel for a more detailed list and integrated discussion of how to implement that list using his field methods.

Depending on the location of the sites, access by boat may be required. Local knowledge of wind, tide and navigational hazards should be obtained prior to operations. A prominent listing of emergency numbers and emergency procedures should be worked out in advance, with particular attention to the needs of SCUBA divers. Reliable, seaworthy vessels which can work in a range of sea conditions and water depths should be procure. More than one vessel type might be required. If you are not fully knowledgeable in these areas and do not posses basic training in navigation and seamanship, retain trained personnel as boat operators, divers, etc. Precautions must be taken against injury during heavy lifting which is typical for seagrass planting.

STAPLE METHOD

Paper coated twist ties (e.g., tomato plant tie-up material)

Dive knife (or similar tool for loosening the bottom to insert the staple)

Mesh float buckets (for holding plants washed free of sediment)

Site markers (stakes, buoys, etc. 3/4" diameter thin wall electrical conduit is relatively inexpensive, comes in 10' lengths and can be easily driven into the sediment although it must be cleaned out between uses). Conduit is difficult to see and should be marked with reflectors. When possible, white PVC pipe should be used.

Waterproof tape measures (100 m variety)

Lead core lines with ribbons on plating intervals if precise spacing is desired or visibility is so poor that a means of orientation is required at depth (line is manufactured for gill nets, survey ribbon must be added)
or

Polypropylene line with ribbons may be floated on the surface as a planting guideline for surface-oriented (non-diving) operations. Buoys are also helpful for orientation as are 3/4" diameter thin wall electrical conduit poles, over which PVC pipe may be slid to mark boundaries. We recommend the conduit because it cuts into the bottom, is more stable in the bottom than re-bar and rusts less (make sure the conduit is cleaned out between uses; fill the conduit with water and shake vertically or tap on a hard substrate - the pressure of the water will eventually force out the sediment in the conduit).

Snorkeling or SCUBA equipment (certified divers only).

If SCUBA diving is required, develop and rehearse a Dive Accident Management Plan. Follow emergency procedures as recommended by recognized safety groups such as the Divers Alert Network (D.A.N.). An ample supply of SCUBA tanks, extra weights (divers work better negatively buoyant here). Dive Flags should be plentiful and obvious.

Tide tables and updated weather forecast.

First aid kit including sun screen and insect repellent and, for divers, an emergency O_2 kit.

Redundant communications equipment.

Appropriate clothing for exposure cannot be overstated. Equipment such as wet suits, wool clothing and foul weather gear which can be worn in the water as well as a wind breaker. Waders may be preferred by some people but as seagrass planting requires much bending over, it is not unusual to overtop waders.

Warm or cold fluids (depending on season), fresh water, and high energy foods.

Polarized sun glasses (enhances visual penetration of the surface).

PEAT POT METHOD

All of the same operational equipment except for the first four items. These should be replaced by the following:

Peat pots (3" square)

Plugger (same size as peat pot)

Tree planting bar

PVC (or equivalent) float collars to support ~ 30 peat pots in a tray.

Durable plastic trays to contain ~ 30 peat pots.

Heavy (~ 10 ga.) wire mesh to fit over peat pots in tray to prevent them from floating out as any air pockets are displaced by water.

CORE TUBE METHOD

All of the equipment for staples except for the first four items. Replace with sufficient core tubes so as to fully utilize the capacity of the transport vehicle.

Surveys

Transit
Meter sticks
Waterproof tape measures (100 m variety)
Random number table
Writing tablets (photocopiable underwater paper on clipboards with prepared data collection sheets are useful). Pencils or grease pencils tethered to the tablet with a generous length of surgical tubing is inexpensive.

(OPTIONAL - Depending on survey technique)

Quadrat: 1 x 1 m 1" PVC sand-filled frame with parachute cord (thin braided nylon line) on 25 cm intersections.

APPENDIX D

Suggested Minimum Components of Proposals and Reports

(modified from Fonseca 1994).

A. Mitigation Proposal

1. Identification of goals
   a. compensatory mitigation or restoration
   b. specify replacement ratio and final acreage

2. Description of impact site survey methodology

3. Site selection criteria and list of sites

4. Location and availability of donor material/demonstration of appropriate collection permits

5. Planting methodology

6. Spacing and spatial arrangement on site

7. Monitoring specifications
   a. identification of variables and methods of collection
   b. monitoring and reporting frequency and duration (suggest minimums of 4 times in year 1, 2 times in year 2, and annually thereafter; this frequency allows implementation of Item 8.
   c. monitoring interpretation criteria

8. Specify criteria for remedial planting

9. Specify criteria for success (e.g., acreage of seagrass cover to be generated [1b], species, duration of unassisted persistence).

10. Specify duration of responsibility and consequences of non-compliance with Items 1-9.

B. Time Zero Report

1. Results of impact site survey and statistical relevance of the survey methodology.

2. Documentation of implementation as compared to the descriptions of Items 1-6 above.

C. Progress Reports

1. Results of monitoring as described in Section A, Item 7, above.

2. Identify and document any remedial action taken

3. Provide best professional estimate of likelihood of meeting Item 9, Section A.

D. Final Project Report

1. To improve subsequent projects, review operational errors/shortcomings in the context of the original work statement.

2. Identify and document compliance with all stated requirements, with particular attention to Section A, Items 1, 7b, 8, 9, and 10.

APPENDIX E

Example Propeller and Mooring Scar Restoration Plan

I. BACKGROUND

The appropriate scale for the restoration should be determined using Habitat Equivalency Analysis (HEA) methodology (Attachment I).

II. RESTORATION APPROACH

The restoration of seagrass scars created by vessel impacts represents is a viable approach to off-site restoration. Restoration efforts will should on seagrass transplanting of scars in heavily injured *Thalassia testudinum* (turtlegrass) seagrass meadows such as described by Sargent et al. (1995) within the Florida Keys. Seagrass beds can be scarred by many activities, but scars are most commonly made when a vessel is moored and the ground tackle gouges the bed or the vessel operates in areas vegetated by seagrasses that are too shallow for the vessel to avoid contact with the seafloor. The vessel's hull and/or propeller tears and cuts up the leaves, stems and roots of the seagrasses, typically leaving long, narrow, trench-like furrows devoid of seagrass. A typical prop scar created by a small vessel (less than 6.5 m in length) is approximately 0.25-0.5 m wide and 0.1-0.5 m deep. Larger vessels with twin propellers or inboard engines (greater than 6.5 m in length) can produce deeper (0.25-0.75 m) and wider trenches (0.5-1.5 m). While smaller scars may naturally recolonize over several years, some scars, especially in *Thalassia* seagrass beds experiencing moderate tidal currents or wave action, persist for decades and can enlarge from erosion (Zieman, 1976). The slow growth rate of *Thalassia* contributes to its comparatively slow recolonization of the bare sediments in scars.

One technique for restoring slow-growing seagrass species such as *Thalassia* focuses on planting another seagrass species such as shoalgrass, *Halodule wrightii*

(*Halodule*) to achieve a "compressed succession" (Durako et al., 1992; sensu Fonseca, 1994). The compressed succession is a planting technique intended to achieve a more rapid rate of seagrass recovery by temporarily substituting the faster growing *Halodule* for the slower growing *Thalassia*. This sequence promotes more suitable conditions for *Thalassia* to recolonize the scar while stabilizing the sediment and establishing functional seagrass habitat.

III. RESTORATION SITE SELECTION

There are, however, a number of management decisions that can be made within the permit process to ameliorate a loss in habitat and better approaches the goal of no net habitat loss. Mitigation in its broader definition typically also includes impact avoidance and minimization (the latter term unfortunately implying an acceptable net loss of acreage). In practice, avoidance and minimization are sometimes difficult to achieve. The existence of techniques to transplant seagrass has often been used to justify the destruction of existing, productive habitat but this approach has consistently produced a net loss of habitat. This net loss of habitat occurs for a number of reasons: one reason is that because the permit-associated activities that destroy seagrass beds in the first place typically are long lasting (i.e., creation of channels, bridges, bulkheads) and do not allow enough area for on-site planting to offset the loss of habitat.

If planting is considered at a location not on the original impact site (off-site compensatory mitigation), that site would preferably not be an area that itself has lost seagrass to some other impact (i.e., if one permits a loss of seagrass for some form of coastal development [e.g. -1 acre] and plants an equivalent area [+1 acre] onto a site which had previously lost seagrass [a previous loss of -1 acre] but was not associated with the project at hand, then the net change in habitat is: [-1 + -1)] +1 = -1 acre; because only the repair of the original problem was addressed, the new, most recently impacted site then constitutes a net loss of local habitat).

Moreover, what if a site chosen for planting does not currently support seagrass? Selecting an appropriate planting site is the single most important step in the entire process. If an off-site planting area must be selected, whether it be for restoration or mitigation, it must pass a simple, but exacting, test: "If seagrass does not currently exist at the (chosen) site, what makes you believe it can be successfully established?" (Fredette et al. 1985). In the absence of site history information, one must then assume absence of seagrass indicates some inherent difficulty in colonization or persistence of seagrass. The events influencing the colonization process are sometimes difficult to document because they are often aperiodic, yet acute events (e.g., extreme low tides, storms, migrating rays excavating the bottom). Naturally unvegetated sea floor should not be substituted for vegetated bottom as this typically creates only a transient seagrass bed and alters, not necessarily improves, exiting habitat functions. There are few off-site compensatory mitigation sites that do not involve habitat substitution or can satisfy the no-net-loss goal.

Planting sites must meet (at least) the following criteria:

1) they are at similar depths as nearby natural seagrass beds;
2) they were anthropogenically disturbed;
3) they exist in areas that were not subject to chronic storm disruption;
4) they are not undergoing rapid and extensive natural recolonization by seagrasses;
5) seagrass restoration had been successful at similar sites;
6) there is sufficient acreage to conduct the project; and,
7) similar quality habitat would be restored as was lost.

In the case of scarred habitat, scarring can be an ongoing impact on seagrass meadows and restoration efforts should be conducted at locations that provide protective management, such as restrictions on power vessel operation where restoration is less likely to be disturbed by further scarring. Additional sites may be considered outside of such management areas where other site characteristics or circumstances exist which will minimize the threat of future injury from vessel groundings.

Preliminary site selection of scars should encompass the inspection of existing high resolution vertical aerial photography or detailed on-site mapping Low level vertical photos are required to quantitatively delineate areas. Photographs should be inspected, and scars identified and measured to calculate total area. If existing aerial photographs are not adequate, new aerial photography should be collected. Following preliminary selection, the sites should be verified for the presence of seagrass adjacent to the scar and for plantable unconsolidated sediments within the scar. Verification should be conducted by snorkel or SCUBA divers, depending upon water depth at the site. Plantable unconsolidated sediments in a scar should be medium to fine grain and at least 10 cm thick. Sediment thickness should be determined by inserting a probe into the sediment approximately every 5 m along the length of the scar. Scars should be targeted in areas that at the time of the survey appear to be susceptible to additional erosion and scar expansion, particularly as the result of disturbance caused by water motion (e.g., waves, tidal currents).

IV. METHODS

A. Planting Area, Site Marking and Site Preparation

We present here guidance for propellor scar restoration; planting broader areas (e.g. mooring gouged areas) would follow similar procedures. Using a conservative estimate for scar width of 0.5 meters, the planned acreage should require delineating X linear meters of scar (Area in m^2 / 0.5); this estimate is conservative given that narrower scars translates into a greater linear distance needed to restore. The location of each scar selected for planting should be established using a differentially corrected Global Positioning System (GPS). Each end of the selected scar should be identified with a permanent marker for positioning and the distances calculated in a Geographical Information System (GIS). Maps delineating the sites and the location of scars should be produced with GIS.

B. Planting Species and Technique

The selected scars should be planted with planting units of shoalgrass, *Halodule wrightii* to achieve a "compressed succession" (attributed to M. Moffler, Durako et al., 1992; *sensu* Fonseca, 1994). The compressed succession is a planting technique intended to achieve a more rapid rate of seagrass recovery by temporarily substituting the faster growing *Halodule* for the slower growing *Thalassia*. This sequence promotes more suitable conditions for *Thalassia* to recolonize the scar while stabilizing the sediment and establishing functional seagrass habitat.

C. Planting Methods

Planting should occur during April and May, months which present optimal environmental conditions for planting. The planting method to be used should use commercially available "peat pots" (Fonseca et al., 1994). Peat pots (one peat pot = one planting unit) are made of an organic, compressed peat material with a surface area of 7.6 cm^2 and approximately 7 cm deep. A sod plugger of the same dimensions as the peat pot is used to extract plugs from the donor seagrass bed which is then extruded into the peat pots (see Fonseca, 1994 and Fonseca et al, 1994 for detailed description of method). The donor beds should be located on shallow, sandy shoals where *Halodule* grows at densities of at least 3,000 shoots per m^2 yielding planting unit shoot densities of at least 17 shoots per planting unit. Donor plugs should be extracted at no less than 25 cm between plugs to minimize any effects on the donor beds.

Prior to extruding a plug of *Halodule*, approximately 10 grams of constant release (70 day) phosphorus fertilizer (0-39-0, nitrogen-phosphorus-potassium) or an equivalent form should be added to each peat pot. Phosphorus has been shown to be a highly limiting nutrient in carbonate sediments such as are found in the Florida Keys (Powell et al., 1989; Fourqurean et al., 1995). Plugs should then be planted at 1.0 m intervals in the scars selected for restoration.

V. SEAGRASS TRANSPLANT MONITORING

Monitoring of the restoration project is necessary to provide data required to evaluate the viability of the restoration project based on the performance standards identified in Section VI and to permit timely identification of problems or conditions that may require corrective action to ensure the success of the restoration project. Restoration monitoring herein should be in accordance with the following terms and specifications.

A. Monitoring schedule and activities

Field collection of data for performance monitoring should occur for four years after planting. Original plantings should be monitored for three years and potential remedial plantings in Year 2 should be monitored for three years for a total monitoring period of four years. Under this schedule the monitoring would be conducted as follows:

Year 1 - day 60, 180, 365
Year 2 - day 180, 365
Year 3 - day 180, 365
Year 4 - day 180, 365

The precise dates are weather dependent. At day 60 of Year 1, each surviving planting unit should receive an additional spike of constant release phosphorous fertilizer (0-39-0, nitrogen-phosphorus-potassium) to be delivered to each planting unit. Semi-annual refertilization of surviving *Halodule* planting units should be required at each planting unit. Alternatively, bird roosting stakes could be installed ~ every 5-10 m along scars; the roosting birds defacate into the water and fertilize the plantings with their phosphorous-rich defecant. This has been shown to be an extremely effective means of accelerating *Halodule* growth in shallow water and in prop scar restoration (Powell et al. 1989, Progress Report II, Prop Scar Restoration Pilot Study, December 1995). The drawback is that rows of stakes may be mistaken for navigational aids, drawing additional boaters to run alongside, further scarring the adjacent beds. Bird roosting stakes can only be used with appropriate navigational markings to discourage such action.

B. Data Collection

Monitoring should focus on documenting the numbers of apicals at planting time, planting unit survival, shoot density and areal coverage under the following schedule and definitions. This monitoring protocol applies to original plantings for three years (Year 1-3) and to remedial plantings under Section VII for three years (Year 2-4).

1. Apical counts

Prior to planting, one planting unit (i.e. peat pot core) out of every one hundred (100) collected should be examined for the number of rhizome apicals.

2. Survival

Each scar should be examined for survival of all planting units during each survey in Year 1 (60, 180 and 365 days) or until coalescence. Survival of each species should be expressed as a percentage of the original number, but the actual whole number should also be reported.

3. Shoot density

A separate (from survival) random selection of three (3) planting units of *Halodule* per scar or per 100 planted PU (whichever yield the higher sample size) should be assessed for number of shoots per planting unit at each survey time until coalescence begins. After some planting units begin to coalesce, 3 randomly selected locations per scar or per 100 m (100 PU) should be surveyed for shoot density over a 1 meter linear distance along each planted scar at 0.0625 m^2 (25 cm x 25 cm) resolution. Shoot density should be monitored for three (3) years.

4. Areal coverage

The randomly selected planting units (may be same as shoot density selection) should be surveyed for coverage at each survey time starting at day 180 of Year 1. Measurements should be taken at a 0.0025 m^2 (5 cm x 5 cm) resolution prior to coalescence and over a 1 meter linear distance along a scar at $0.0625m^2$ (25 cm x 25 cm) resolution after coalescence for each seagrass species present at each survey time. Areal coverage should be monitored for three (3) years.

5. Video Tape Transects

Five 100 meter transects along randomly selected portions of the planted scars should be video-tape recorded to establish permanent visual documentation of the progression of areal coverage of seagrass through time. A metric tape measure should be laid along the central (long) axis of the scar and should be included in the video tape to allow physical reference of locations within the scar. Video recordings should be taken at each survey time during the monitoring period of three (3) years. Observation-based assessment of success may be substituted for 3 and 4 above, if quadrats are used in accordance with a Braun-Blanquet survey method (see Attachment II) if the data are obtained from the video tape (making the observational data base available for cross-checking). The same number of sample points must be obtained with the same spatial extent (i.e., survey each scar). Similarly, Braun-Blanquet observations of cover at every meter along each scar may also be obtained from the video tape to obtain estimates of planting performance.

C. Reports

Monitoring reports (up to a total of 9) should include copies of raw data gathered in each survey, an analysis of the data, and a discussion of the analysis. Originals of all video tapes recorded since the previous report should be provided with each new report. Originals of all video tapes and other photography should be turned over to the permitting agency following project completion by the party conducting the monitoring.

VI. PERFORMANCE STANDARDS

Although it is the overall objective to restore *Thalassia* at the selected scar sites, performance criteria should be based on the success of the *Halodule* planting as the planting methodology used is designed to expedite the recovery of *Thalassia*.

A. Apicals

A minimum average of one horizontal rhizome apical per unit should be maintained in all original planting and remedial planting.

B. Survival

The survival rate shall be considered successful if a minimum of 75% of the planting units have established themselves by the end of Year 1. If it is determined that less than 75% survival has occurred by the end of Year 1, then remedial planting should occur during the next available planting period to bring the percentage survival rate to the minimum standard by the next monitoring survey.

C. Growth

The third success criteria should be the measured growth rate of bottom coverage. The growth rate should be considered successful if, starting after one year, the planted seagrass in the scars (restoration sites) is projected to achieve 1.55 acres of bottom coverage, with 95% statistical confidence, within the three year monitoring period for original plantings. If this criteria is not met, then remedial planting should occur during the next available planting period.

VII. REMEDIAL PLANTINGS AND/OR PROJECT MODIFICATIONS

If data from a monitoring report establishes that the performance standards described in Section V are not being met or are projected not to be met, remedial plantings of those affected seagrass species should occur. If there is a recurring problem with survival of plantings or replantings in a particular area, remedial planting should occur in another scar within the Sanctuary subject to the approval of permitting agencies.

Based on past experience in seagrass restoration efforts, it is assumed that 30% of the planted area should require remedial planting in Year 2. All original plantings should be monitored for three (3) years in accordance with Sections V and VI. Remedial plantings should be monitored for three (3) years subsequent to the date of a remedial planting.

VII. PROJECT PERMITTING

The seagrass restoration and monitoring outlined in this plan should be implemented consistent with any applicable state or federal permitting requirements. The format of the restoration and monitoring plan outlined in this document may be amended in order to comply with applicable permitting requirements.

IX. CONTRACTOR(S)

The permitting agecny should utilize the services of one or more qualified contractors to implement this restoration and monitoring plan.

X. PERMITTING AGENCY OVERSIGHT OF SEAGRASS RESTORATION PROJECT

The agency should oversee the implementation and monitoring of the seagrass restoration project in order to ensure its implementation in accordance with the terms of this plan. Costs which the agency should incur to provide effective oversight are part of the costs of implementing this seagrass restoration and monitoring plan. Activities which the agency may undertake in order to provide for effective implementation of this plan include, but are not limited to, the following:

a. actions associated with the identification, selection and hiring of any contractor(s) who should implement any part of this plan, including monitoring or remedial actions,

b. oversight of any field work at the project site, including remedial actions,

c. inspection of any completed field work, including remedial actions, to determine whether implementation is in accordance with this plan, including any applicable contract or permitting requirements,

d. review and evaluation of monitoring reports,

e. identification and direction of any actions needed to bring field work, including remedial actions, into compliance with standards for project performance identified in this plan,

f. actions to address NEPA and permitting processes, and

g. actions associated with final site selection.

XI. REFERENCES

Durako, M.J., M.O. Hall, F. Sargent, S. Peck. 1992. Propeller scars in seagrass beds: an assessment and experimental study of recolonization in Weedon Island State

Preserve, Florida. p. 42-53 IN Webb, F.J. (ed.) Proc. 19th Ann Conf. on wetlands restoration and creation. Hillsborough Comm. Coll., Plant City, FL.

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Fonseca, M.S., W.J. Kenworthy, F.X. Courtney, and M.O. Hall. 1994. Seagrass planting in the southeastern United States: methods for accelerating habitat development. Rest. Eco. 2:198-212.

Fourqurean, J.W., G.V.N. Powell, W.J. Kenworthy and J.C. Zieman. 1995. The effects of long-term manipulation of nutrient supply on competition between the seagrasses *Thalassia testudinum* and *Halodule wrightii* in Florida Bay. Oikos 72: 349-358.

Powell, G.V.N., W.J. Kenworthy and J.W. Fourqurean. 1989. Experimental evidence for nutrient limitation of seagrass growth in a tropical estuary with restricted circulation. Bull. Mar. Sci. 44: 324-340.

Progress Report II, Prop Scar Restoration Pilot Study, December 1995.

Sargent, F.J., T.J. Leary, D.W. Crewz, and C.R. Kruer. 1995. Scarring of Florida's seagrasses: assessment and management options. Florida Marine Research Institute, Tech. Rep. TR-1.

Zieman, J.C. 1976. The ecological effects of physical damage from motorboats on turtle grass beds in Southern Florida. Aquat. Bot. 2: 127-139.

ATTACHMENT I. Assessment of Interim Losses

Another goal of many seagrass plantings is an attempt to recoup interim loss of ecosystem functions. This was mentioned earlier as an attribute of functional equivalency. Because the concept of success and functional equivalency are so closely tied, planning for successful restoration and/or mitigation requires early incorporation of interim loss considerations. The manner in which interim loss has been addressed historically has been through adjusting replacement ratios (how much acreage to plant per unit acreage lost). However, the manner in which interim ecosystem losses have been computed has not been consistent. Replacement ratios of less than 1:1 to as high as 5:1 have been proposed (pers. obs.), based on a number of criteria, but that ratio is usually inversely proportional to the degree which a project was in the public interest.

To compute losses though, requires some assessment of not only acreage lost, but how long a time the functions of that acreage was lost to the ecosystem at large before it was returned to pre- or unimpacted levels. Depending on how long one wishes to amortize a loss will influence how much replanting must be done. In theory, if one hectare of seagrass were destroyed today and three hectares were replanted tomorrow and, for argument sake, reached standards of equivalency in three years, then after those three years, the planting would have largely compensated for the total loss of production; the net loss of production over this three year period would be very low. However, it rarely works this way. First, it is very difficult to consistently locate and successfully create new seagrass habitat that meet our site selection criteria (which precludes simply substituting naturally unvegetated bottom for vegetated bottom). Finding large acreage for planting in close proximity to the impacted area is rare, meaning that planting is often done at a site physically removed from the impact area and any functions affected by spatial elements of ecosystem linkages (i.e., geographic setting) are lost. Second, the production that was lost was removed from a specific point in time; ecosystem functions were disrupted and those specific resources are not replaced, such as that year's spawn of herring (e.g. as in the Pacific northwest). Further, if there was a greater hiatus between the time of impact and recovery or the spatial separation were greater, then one could argue that plantings conducted longer after an impact or further away from an impact have less value than ones conducted sooner or nearer.

The injury assessment strategy to calculate interim loss is based on four steps of analysis: 1) documentation and quantification of the injury, 2) identification and evaluation of restoration options, 3) scaling of the restoration project to compensate for the injury over time, and 4) determine the appropriate means of compensation (e.g., monetary or planting). The scaling aspect is the portion of the process that helps standardize the way in which interim losses are computed, irrespective of the habitat type involved. Interim lost services can be considered to be the integral of service lost from some baseline level over time. To compare services lost with those recovered by some remedial action (such as planting seagrass), the product:

square m of habitat lost x time = square m-years,

is set against square m-years of services provided by the planting project, but discounted as a function of time since the initial injury. Discounting is a widely-known economic principle and is a way of computing value of a commodity (such as a unit area of planted seagrass) based on how long it has been since the impact occurred. Plantings that occur longer after an impact are worth less than plantings conducted shortly after an impact and therefore more planting must be done as more time elapses.

ATTACHMENT II. Synopsis of Braun-Blanquet Technique (Braun-Blanquet, J. 1965. Plant Sociology: The study of plant communities (translated, revised and edited by C.D. Fuller and H.S. Conrad). Hafner, London.

The B-B coverage abundance scale is computed beginning at the zero point and at X m intervals along a transect (frequently enough to get some detailed variation, say a absolute minimum of 30 quadrats per transect), place a quadrat (for seagrass I recommend 0.25 m^2 , i.e., 50 cm on a side) on the seafloor. Visually inspect the content of the quadrat and assign a cover-abundance scale value to the seagrass coverage. The scale values are:

0.1 = solitary shoots with small cover
0.5 = few shoots with small cover
1.0 = numerous shoots but less than 5% cover
2.0 = any number of shoots but with 5-25% cover
3.0 = any number of shoots but with 25-50% cover
4.0 = any number of shoots but with 50-75% cover
5.0 = any number of shoots but with > 75% cover.

From the survey of quadrats along a transect, frequency of occurrence, abundance and density of seagrass (or macroalgae, by species in either case) can be computed as follows:

frequency of occurance = number of occupied quadrats / total number of quadrats,

abundance = sum of B-B scale values / number of occupied quadrats,

density = sum of B-B scale values / total number of quadrats.

One might wish to average the frequency, abundance and density values of the various transects or consider stratifying the data in some way that defines the site in some meaninful way. These values can then be used as a comparative basis among sites, pre- and immediately post-impact or post-planting as a means of assessing recovery.

APPENDIX F

Recommendations for Further Reading

The following community profiles on seagrass published by USFWS:

Phillips, R. C. 1984. The ecology of eelgrass meadows in the Pacific northwest: a community profile. U.S. Fish Wildl. Serv. FWS/OBS-84/24. 85 p.

Thayer, G.W., Kenworthy, W. J., Fonseca, M.S. 1984. The ecology of eelgrass meadows of the Atlantic coast: a community profile. U.S. Fish Wildl. Serv. FWS\OBS-84\02. 147 p. Reprinted 1985.

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Specific readings on seagrass restoration and management (see references for full citation).

Batiuk et al. 1992. (Entire document).

Churchill, Cok, and Riner 1978.

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Fonseca, et al. 1982; 1984; 1985; 1987c; 1988, 1994.

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Kenworthy and Haunert 1991. (Entire document).

Lewis, R. R. 1987, 1989.

Merkel and Hoffman 1988.

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Neckles 1994. (Entire document).

Phillips 1982.

Thayer 1992 (Entire document).

Thom 1990.

Wyllie-Echeverria et al. 1994a. (Entire document).

Muehlstein, L.K. (1989): review of wasting disease phenomena.

Phillips, R.C. and C.P. McRoy (1990): handbook of seagrass research method.